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EFFECTS OF HIGH POWER LASERS, NUMBER 4

Stuart G. Hibben, et al

Informatics, Incorporated

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INTRODUCTION

This is the fourth compilation of abstracts of Soviet studies on high power laser technology, covering material published from April through September 1974. Articles are grouped by laser interaction with metals, dielectrics, semiconductors, miscellaneous targets, and laser-plasma interaction.

A first-author index and an index of source abbreviations are appended.

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This is the fourth compilation of abstracts of Soviet studies on high power laser technology, covering material published from April through September 1974. Articles are grouped by laser interaction with metals, dielectrics, semiconductors, miscellaneous targets, and laser-plasma interaction.

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Abstracts

1. Metal Targets

Barchukov, A. I., F. V. Bunkin, V. I. Konov, and A. A. Lyubin. Study of a low-threshold breakdown of gases near solid targets by CO_2 laser radiation. ZhETF, v. 66, no. 3, 1974, 965-982.

The process of generation and development of plasma near solid targets due to pulsed CO_2 laser radiation is analyzed. In particular the mechanism is discussed of low-threshold breakdown of gases near the targets, and theoretical explanations are outlined. Experiments were performed using a multiple-mode pulsed CO_2 laser with transverse discharge; the test setup is shown in Fig. 1.

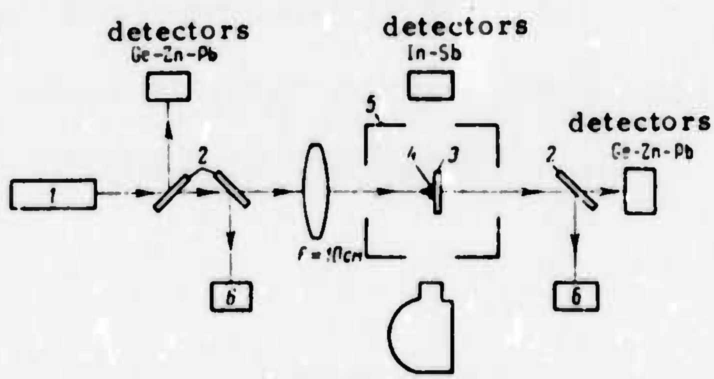

Fig. 1. Experiment Arrangement.

1- Pulsed CO_2 laser; 2- NaCl splitters; 3- target; 4- plasma; 6- calorimeter.

The laser was focused with an NaCl lens (f = 10 cm) on a target surface, located in a chamber charged with the test gas: argon at pressures 0.1-7 atm, and air at 0.1-1 atm. Targets used were of both transparent and

opaque materials, including BaF_2, NaCl, metals, textolite, graphite, and epoxy resin. Dynamics of generation and development gas breakdown were investigated by means of a high-speed SFR camera operating in a continuous recording regime. Laser energy was varied from 0.3-5 joules, and duration τ = 10-15 μsec. Excitation of light-detonated waves was found to occur in gases at anomalously low radiation intensities on the order of $I = 10^7$ watt/cm^2, without any preliminary formation of a plasma absorption source due to external factors. The study goes into the dynamics of vaporization of solid targets, and of the gas dynamic structures of the resultant stationary plasmatron. New theoretical results are obtained relating to temperatures and pressures in the region of one-dimensional flow of vapor near the target. The authors conclude that the occurrence of low-threshold breakdown near solid targets may be a result of optical surface destruction; this could be a limiting factor in the maximum power obtainable from the laser before breakdown in the output region.

Arifov, U. A., V. V. Kazanskiy, V. B. Lugovskoy, and V. A. Makarenko. Spiked emission of electrons from a tungsten target under various laser operating regimes. IAN Uzb, no. 2, 1974, 42-45.

Results are described of an experimental study on peak electron emission from a tungsten target, during its irradiation by uniform laser radiation. The active element was a ruby crystal of high homogeneity with leucosapphire faces. Pumping was by an IFK-15000 flashlamp; the ruby was cooled by water circulation. The laser developed 2 μs pulses containing a large number of chaotic spikes.

Electrolytically polished poly- and single-crystals of tungsten were irradiated in vacuum at 10^{-6} torr. Targets were not allowed to heat up, but their surfaces were cleaned by laser radiation of increased intensity before each series of measurements (30 irradiations). A double convex lens of f = 0.07 m was used for focusing the radiation. Targets were placed at the lens focus as well as 30 mm away from it, in a region where peak emission was the highest. Target emission as well as laser signals were recorded by a five-beam oscillograph.

Graphical results are included showing the maximum smoothed value of emission pulse I_{max} and the total charge of emitted electrons q as functions of laser radiation intensity. Maximum variations in integral temperature T_i. peak temperature T_n, and total temperature T are also illustrated. The dependence of average peak emission current on laser radiation intensity was found similar for all regimes of laser radiation. A statistical analysis was also made for the correlation between parameters of emission and laser spikes, and correlation coefficients were determined. The authors conclude from their results that thermoelectron emission is less probable, under conditions of the performed experiments, than it would be under processes with characteristics of multiphoton photoeffects.

Kovalenko, V. S., V. S. Chernenko, V. P. Kotlyarov and N. I. Prikhod'ko. Laser heating of high-speed steel. IN: Tekhnologiya i organizatsiya proizvodstva. Nauchno-proizvodstvennyy sbornik, no. 12, 1973, 43-45. (RZhMetal, 4/74, no. 4I870). (Translation)

High-speed steel, following the usual thermal treatment routine, was subsequently exposed to laser heating. Photon-beam heating was obtained using the SLS-10-1 apparatus with the following parameters: maximum emission energy = 8 joule and pulse durations are 2 and 4

millisec. The heated zone consists of three layers: 1) the near-surface layer; 2) the layer with undissolved carbides; and 3) the zone of additional high-speed tempering. In photon-beam heating the first layer contains no carbides. To choose the optimum conditions of tempering that lead to the conversion of the largest portion of residual austenite in the photon-beam heating zone, various regimes of tempering were investigated at temperatures of 500 to 600° C. Best results were obtained on tempering at 560° C, 3 hr (?). Photon-beam heating of thermally treated P 18 steel increases the stability of residual austenite in the photon-beam heating zone.

Kazanskiy, V. V., V. B. Lugovskoy, V. A. Makarenko, and G. A. Ismailova. <u>Angular distribution of charged particles emitted from tungsten under the action of a ruby laser.</u> IN: Sb. Fizicheskiye yavleniya pri bombardirovke tverdogo tela atomnymi chastitsami. Kniga 1. Tashkent, Fan, 1973, 157-163. (RZhRadiot, 4/74, no. 4E198). (Translation)

A free-running ruby laser is applied. Data on angular distribution of electrons and ions are compared; the data were obtained from irradiating poly- and monocrystal tungsten targets under varying angles of incidence on the target. It was established that in almost every case the distribution was anisotropic. Peculiarities of distribution are more dependent on the angle of incidence of emission on the target than on the target structure.

Levinson, G. R., and V. I. Smilga. Change in reflectivity of metal films during heatup by short laser pulses. Kvantovaya elektronika, no. 5, 1974, 1235-1238.

Reflectivity of thin metallic films was experimentally investigated by registering the mirror image of continuous laser probe radiation from a target. The technique permitted observations during and after the period of film irradiation. Ag, Al, Au and Cu film specimens were obtained by thermal deposition in vacuum ($p = 10^{-5}$ Torr) on polished quartz substrates. Irradiation of the specimens was with a pulsed N_2 laser ($\lambda = 337$ nm) at a pulse duration of 8 nsec and pulse power up to 10^4 watts. The experimental sketch is shown in Fig. 1. A short description is outlined on the experimental procedure.

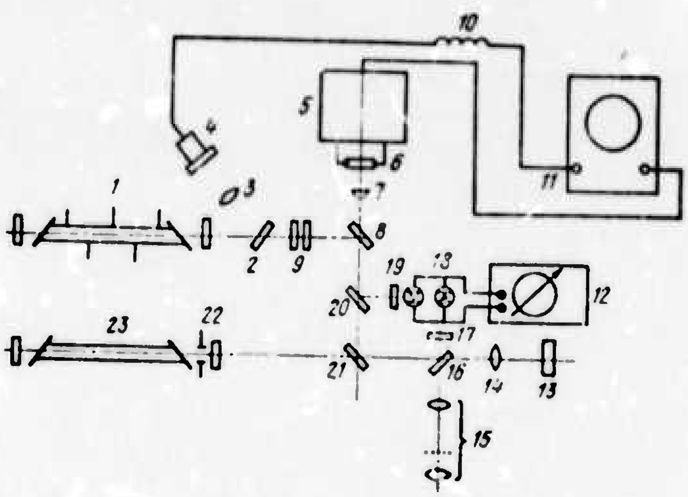

Fig. 1. Experimental sketch.

1- N_2 laser; 2, 16, 20- splitters; 3- quartz lens (f = 30 mm); 4- coaxial photocell; 5- photomultiplier; 6- Interference filter ($\lambda = 632$ nm); 7- cylindrical lens; 8, 21- dichroic interference mirror; 9- calibrated optical wedge; 10- delay line, 120 nsec; 11- time interval recorder; 12- photogalvanometer, 13- test specimen; 14- quartz objective; 15- dioptic tube; 22- iris diaphragm; 23- c-w He-Ne laser.

It was found that in the flux density range for which the maximum temperature of film heating does not exceed its melting point, the change in reflectivity from Au and Cu specimens has an inverse character which is reproducible during many radiation pulses without any change in the composition of the film surface. A sample oscillogram of variations in amplitude of the reflected probe radiation for Cu film of thickness = 91 nm at an intensity of 9.4×10^6 w/cm^2 is shown in Fig. 2.

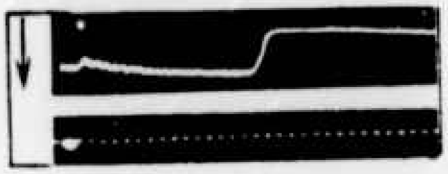

Fig. 2. Typical oscillogram of the change in reflectivity of irradiated Cu film. Arrow shows the direction of reflected signal increase. Time mark = 20 nsec.

It is seen that the level of reflectivity reduction equals 25%; duration of the pulse leading edge does not exceed 20 nsec and the trailing edge - 150 nsec.

Variations in the reflection of the tested metallic films are assumed to be connected purely with temperature effects. This assumption is theoretically verified by calculating temperature dependence of the reflectivity of thin metallic films, taking into account dimensional effects. Calculated and experimental results of reflectivity reduction for these films during their heating up to the melting point are included. From the obtained results, it may be concluded that during irradiation of thin metallic films by short laser pulses their reflectivity decreases, and the value of this decrease may be calculated with reasonable accuracy.

Buravlev, Yu. M., I. V. Karpenko, and B. P. Nadezhda. Characteristics in transformation of steel structures by laser radiation. FiKhOM, no. 3, 1974, 13-17.

Effects of laser radiation on the surface layer of structural steel specimens with different thermal processing are reported. Investigations were conducted with the Luch-1M laser, operating in a free-running regime at pulse energy of 0.5-2 joules and pulse duration of 2 millisec. Laser radiation was focused on the surface of type ShKh 15 and 40 Kh steel specimens in an annealed and hardened martensite state. Structural changes in the laser interaction zone were studied in thin sections by means of microhardness meters and metallographic microscopy.

It was seen that structural changes of craters in the surface layer in steel specimens, and the erosion of specimens, depended on their thermal processing history. Thus the high erosion of hardened specimens in comparison to the erosion of annealed may be explained by the lower thermal conductivity of the former, and also because of the presence of internal stresses and microcracks in the hardened types.

The effect of laser power on phase and structural transformation in steels of different initial structural states was further investigated by irradiating the specimens with different pumping energies, from 625 to 1000 joules (Table 1). It is seen from the table that the thickness of white layer, i.e. the zone of annealing and hardening in steel after interaction with the laser pulses, is a function of the laser pulse power. A comparison of effects for two specimens of steel is shown in Fig. 1.

Table 1

Variations in average thickness of white layer zone of hardening and annealing for ShKh 15 steel at different pumping energies.

Pumping Energy, Joule.	Layer thickness, mm.			
	Annealed Steel		Hardened Steel	
	White layer	Hardening zone	White layer	Annealing zone
625	0.75	0.015	0.09	0.04
700	0.11	0.02	0.11	0.04
850	0.11	0.03	0.14	0.05
1000	0.12	0.03	0.14	0.05

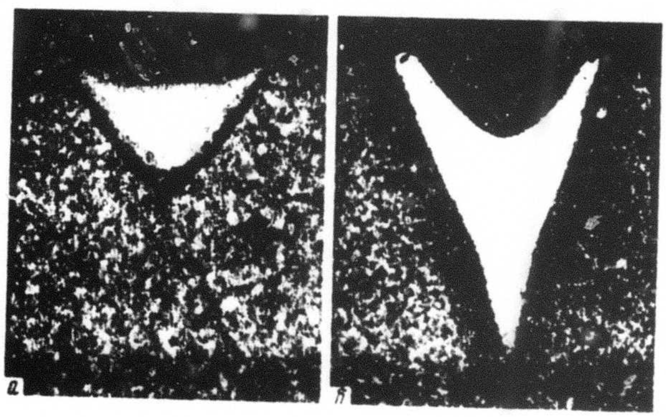

Fig. 1. Section of laser crater from annealed (a) and hardened (b) type ShKh 15 steel, x 150.

Papirov, I. I., S. S. Avotin, and E. P. Krivchikova. Deformation of beryllium single crystals by laser radiation. FiKhOM, no. 2, 1974, 18-21.

This is an extension of work by Papirov et al, reported previously (Sel. Mat'l. Sov. Tech. Lt., Sept. 1973, 9). Structures of beryllium single crystals with (0001) and (1120) orientations were studied metallographically after irradiation by laser pulses at ambient temperatures of 77°, 300° and 580° K. Irradiation at 580° K was done in a resistance oven with a laser access hole, while for irradiation at liquid nitrogen temperature, the specimens were fixed to the inner wall of a cylindrical foam plastic vessel. Exposure was to a type GOR-100 M free-running ruby laser developing 30 j, one millisecond pulses. Laser pulse power was held constant throughout. After exposure, plastic deformation was studied by means of an optical microscope along the deformed profile on the surface, and also after electrochemical surface etching of the specimens.

The character of plastic deformation near the crater was found to depend on the ambient temperature of the irradiated crystals, and significantly differed from deformations in static conditions. The width of the deformation zone increased with rise in temperature, namely from 0.5-1 mm at 77° K up to 2-3 mm at 580° K. The laser action gave rise mainly to twinning on the basal plane of the crystals and to twinning and glide lines on prism faces. The number of twins formed directly in the crater decreased with increase of temperature. Movements of twinned boundaries became easier with increase in temperature. It is concluded that the movement of twinned boundaries is a thermally activated process.

2. Dielectric Targets

Bayev, V. M., A. N. Savchenko, and E. A. Sviridenkov. Study of the breakdown of ruby by multiple and single ultrashort pulses. ZhETF, v. 66, no. 3, 1974, 913-919.

Breakdown of ruby was investigated, using both single and trains of ultrashort laser pulses at $\lambda = 1.06\mu$. The experimental system for studying the breakdown is shown in Fig. 1; a detailed description is outlined by the authors on the experimental procedure.

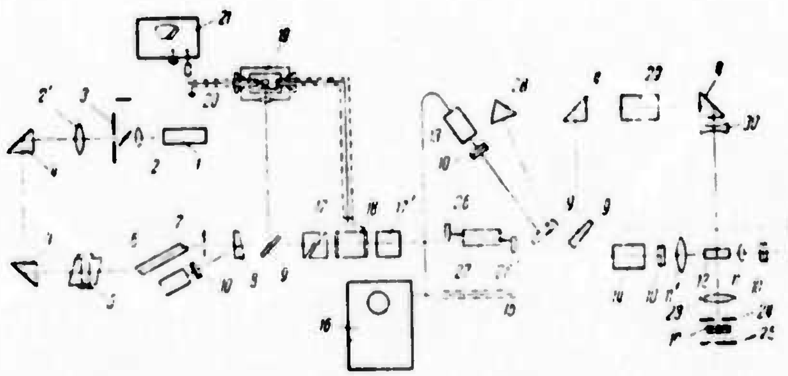

Fig. 1. Test Setup.

1- He-ne laser; 2- telescopic system; 3, 7, 24- diaphragm; 4, 22- prism; 5, 6, y, 8- Nd glass laser system; 9- splitter; 10- filter; 11, 23- lens; 12- specimen; 13, 14- photoelement; 15, 20- cable; 16- oscillograph; 17- Glan prism; 18- Pockels cell; 19- trigger; 21- hv source; 25- film; 26- mirror; 27- Nd glass amplifier; 28- calorimeter; 29- KDP crystal; 30- negative lens.

During action of pulse trains on the ruby, a cumulative effect was observed due to the reduction of electrons in the conductivity zone to a low n-type level with lifetime T = 13 nsec; this results in a lowering of optical stability in the crystal. This effect was investigated as a function of the pulse repetition period in the train. The action of ultrashort pulses on ruby was observed to cause self-focusing, which leads to point destruction in the vicinity of the moving focus. Intergrowth of these self-focusing filaments is found, in a direction towards the radiation source.

It is concluded that during optical breakdown of ruby by ultrashort pulses, the determining role in radiation absorption is played by direct ionization of atoms of the crystal lattice in a strong electromagnetic wave field, and not by cumulative shock ionization. The authors also point out that the procedure used in the cited work allows them to determine relaxation of radiation absorption in intervals on the order of 10^{-11} sec.

Amenitskiy, N. A., N. Ye. Kask, L. S. Korniyenko, V. V. Radchenko, G. M. Fedorov, and D. V. Chopornyak. Vozdeystviye izlucheniya OKG v millisekundnom diapazone dlitel'nostey na opticheskoye steklo (Effect of laser radiation in the millisecond range on optical glass). NII yadernoy fiziki Mosk. un-ta. Moskva, 1973, 62 p. (RZhF, 3/74, no. 3D1112). (Translation)

The dependence of the damage threshold of an optical glass on the duration of laser radiation interaction was studied in the 1-10 msec, range with the laser operating in both spike and quasicontinuous regimes. Relationships of these two regimes of multi-mode generation were of different types, depending on the fine structures of radiation distribution in the focal region of the lens. Energy absorption was the main factor which determined the threshold of volume and surface destruction. The nature of surface processing was found to have no effect on the damage threshold. Fusion and plastic deformation in the test glass were detected at a pre-threshold regime. It was

observed that prior to damage, stresses were developed in the glass, the values of which were comparable with the theoretical strength of the glass. Destruction of optical glass with visible nonmetallic impurities was also investigated. A relationship was established for the damage threshold power as a function of impurity dimensions. Thermal self-focusing of laser radiation in optical glass was studied in prethreshold regimes at levels below specimen destruction.

Danileyko, Yu. K., A. A. Manenkov, V. S. Nechitaylo, and V. Ya. Khaimov-Mal'kov. Optical properties and laser destruction of "ideal" single-crystal ruby surfaces. FTT, no. 6, 1974, 1725-1727.

Comparative intensity of laser radiation scattering and surface damage threshold were determined in ruby crystals either mechanically polished or heat treated at temperatures of 1600-1700° C. Scattering measurements were done with a 3 mw He-Ne laser beam focused to a 15 μ diameter spot on the crysta' surface.

Measurements showed that surface strengthening against laser radiation can be achieved by removal of defective surface layers. Subsequent measurements of scattering from the (1120) and (1121) faces of the ruby crystal revealed that scattering intensity from the perfect surfaces obtained by thermal vaporization of the defective layer is three orders of magnitude lower than that from the mechanically polished surfaces. Damage threshold on a perfect surface from a high-power single-mode ruby laser was accordingly found to be about one order of magnitude higher than on a mechanically polished surface.

The authors conclude that the new method of thermal vaporization is the most effective in obtaining an optically perfect, defect-free surface in ruby, and presumably other laser crystals, thus providing the very low scattering and high strength necessary for high-power laser radiation.

Kondratenko, P. S., and B. I. Makshantsev. <u>Propagation of an absorption wave of laser radiation in a solid transparent dielectric.</u> ZhETF, no. 5, 1974, 1734-1739.

The authors discuss the problem of self-similar motion of cumulative ionization waves, generated by laser radiation in solid transparent dielectrics. It is known that microimpurity absorption of laser radiation leads to the local heating of solid transparent dielectrics up to temperatures $T = 10^4$ degree. This in turn leads to local concentration of sufficient free electrons n_e, such that further ionization takes place by way of electron collisions. Electron concentration is determined as a function of temperature, $n_e = n_e(T)$.

A system of equations is obtained for the propagation of laser absorption waves, generated due to thermal cumulative ionization of the substance around absorbing inhomogeneities. The expressions obtained give values which characterize the laser radiation absorption wavefront and its velocity. Boundary conditions are determined for the stability of self-similar solutions. The problem is discussed for two limiting cases, one of which corresponds to a quasiclassical electromagnetic field, and the other to the presence of strong reflection from the absorption wavefront. Critical values of the light flux intensity q_{crit} and typical values of some parameters quantities are estimated for both limiting cases.

Pavshukov, A. V., M. B. Svechnikov, and V. M. Tyunis. <u>Heating of multilayered dielectric coatings by a laser beam.</u> OMP, no. 6, 1974, 8-10.

Temperature and absorptivity of 11-layer $ZnS\text{-}MgF_2$ coatings heated by a laser beam at $\lambda = 1.06\ \mu$ were determined experimentally. This was done by observing spectral shift of the secondary peaks of the coating's reflection coefficient, R. Earlier experiments have suggested an analogy between the R variations from radiation effects and those caused by heating. Tests confirmed that reversible variations of R from laser radiation effects are caused by a shift of R secondary peaks due to thermal effect of laser radiation.

The experimental assembly (Fig. 1) and the procedure for measurements are described. Pulses from a free-running Nd-glass

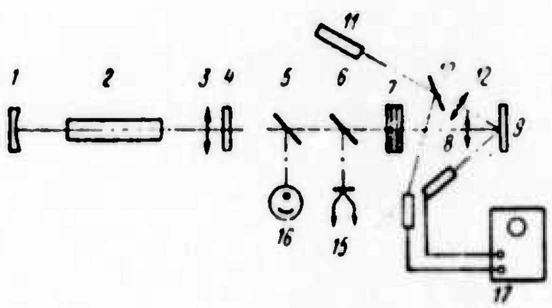

Fig. 1. Experiment for measuring coating temperature: 1- mirror; 2- Nd glass laser; 3, 8 and 12- focusing lenses; 5, 6 and 10- beam splitters, 7- calibrated filter, 9- test coating on glass substrate, 11- auxiliary He-Ne laser, 13 and 14- photomultipliers, 15- carbon calorimeter; 16- photocell, 17- oscilloscope.

laser had 1 msec duration and 250 joule energy, which was held constant within ± 3%. The He-Ne laser beam was focused in the center of the irradiated area of the coating. The temperature to which the coating was heated by the Nd glass laser radiation was determined from the differential in reflectivity R to the He-Ne beam between the heated and unheated dielectric surface. It is assumed that temperature values thus obtained are the average temperatures, i.e., radiation is absorbed uniformly over the entire irradiated area. It was thus found that the coating is heated to 100-120° C by radiation at energy density close to damage threshold. The coating attains maximum temperature in about 500 μsec after pulse emission starts. During that time, heat propagates through the substrate as well, hence allowance was made for heat transfer to the substrate when calculating energy absorbed by the coating. In this way absorptivity of the coatings was found to be 5×10^{-4} to 7×10^{-4}, and was independent of temperature in the 25-150° C range. This finding appears to indicate a linear absorption by micro defects.

Aleshin, I. V., Ya. A. Imas, V. L. Komolov, and V. S. Salyadinov. Surface luminescence of transparent dielectrics under the action of laser radiation. OMP, no. 7, 1974, 72-75.

Luminescence of the surface layer of transparent dielectrics was experimentally detected from the action of subthreshold laser flux, and was localized within the limits of the irradiated spot. Experiments were conducted using a Q-switched laser with telescopic resonator, radiation from which was focused on specimens placed in a vacuum chamber ($p = 10^{-5}$ torr). Spectral response of the surface luminescence was studied by means of a photomultiplier with interference filter in the 240-540 nm range and with a fast spectrograph in the 570-700 nm range. Specimens investigated were type KI quartz glass, K8 optical glass and fluorite.

Experimental results show a characteristic pecularity in subthreshold luminescence: its intensity quickly decreases during multiple surface exposure at the same spot. In case of spiked laser pulses, a significant decrease in luminous intensity starts from the second or third spike, and luminescence does not recover for several hours after irradiation. The level of luminescence signal is independent of specimen materials, but sharply increases in switching from specimens with polished surface to specimens with a dull surface. Luminescence intensity also depends linearly on laser flux density in the $0.1\,q - q_{thres}$ range. The subthreshold luminescence spectrum (Fig. 1a) is seen to be significantly different from that of a plasma flare (Fib. 1b). Fig. 2 shows the results

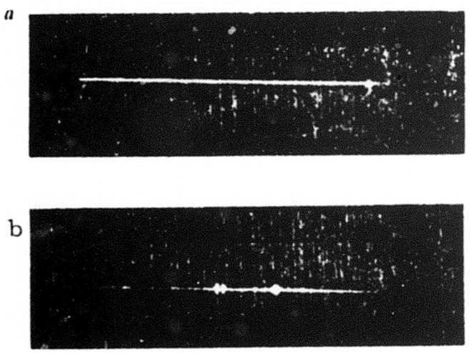

Fig. 1. a) Luminescence spectrum of quartz glass; b) plasma flare in quartz glass.

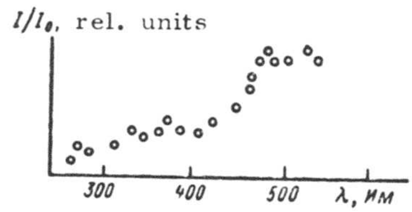

Fig. 2. Subthreshold luminescence spectrum of quartz glass.

of the subthreshold luminescence spectrum.

The authors point out that since the amplitude of luminescence signal depends upon surface relief, measurements of the subthreshold luminescence could be used as a nondestructive method for controlling the surface quality of transparent dielectrics.

3. <u>Semiconductor Targets</u>

Ivanov, L. I., Yu. N. Nikiforov, and V. A. Yanushkevich. <u>Variations in electric conductivity of semiconductor crystals during passage of the shock wave from a laser pulse</u>. ZhETF, v. 67, no. 1, 1974, 147-149.

The kinetics of resistance ρ variations is analyzed in p-Si, and p- and n- Ge whiskers, induced by shock wave from interaction with laser radiation at 10^8 - 10^9 w/cm^2 power density. The whiskers were sandwiched between a copper foil and a quartz substrate bonded together and were then immersed in an optically transparent liquid (distilled water or oil) to lower the generation threshold of the shock wave. A shock wave with a $\sim 10^4$ kbar amplitude P was generated by 50 nsec pulses from a ruby laser, focused on the copper foil surface to eliminate the photoeffect of direct or scattered radiation. The shock wave P in the specimen was calculated to be 1.2×10^3 to 4.8×10^3 atm. with allowance made for reflection from the foil-glue and glue-whisker interfaces.

Oscilloscope traces, e.g. Fig. 1, showed that, at 290° K,

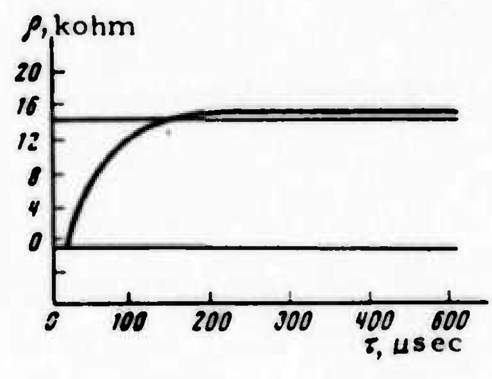

Fig. 1. Resistance ρ of p-Ge whisker during passage of shock wave from laser pulse.

ρ of all whiskers, irrespective of their conductivity type, decreases sharply when a shock wave strikes the whisker. The relaxation time of the recovery process varies from a few microseconds for p-Si and n-Ge to several tens of microseconds for p-Ge. The recovery of ρ after passage of a shock wave is related to formation of stable crystal defects.

The observed drop in ρ at the time of shock wave impact is tentatively attributed to ionization or transition from semiconductor to metal. A large difference in magnitude of ρ decrease in p-Ge and p-Si may be attributed in part to difference in pressure at the shock wave front, owing to different impedances of the transparent liquids used (water for p-Ge and oil for p-Si).

Komolov, V. L. Variational approach to the problems of heat breakdown of a semiconductor while exposed to light. ZhTF, no. 5, 1974, 944-949.

A variational method of solving problems on the thermal instability of a semiconductor due to light flux is suggested. In discussing thermal breakdown of semiconductors, the author assumes that light absorption is effected by electrons in the conduction zone and is a function of the temperature. An approximate law of absorption is obtained with the use of power functions. Solutions are obtained for two simple one-dimensional problems and also for a disc of finite dimensions with a Gaussian distribution of light beam intensity and boundary conditions of the third kind. The author notes that an accurate solution of the thermal breakdown problem is possible only for one-dimensional regions (infinite plate, long cylinder, sphere). However, it is interesting from the practical viewpoint to note that the treatment is applicable for calculating

optical elements of high power lasers (output window, filters, etc). The variational method is also very useful for solving idealized one-dimensional problems, as it leads to simple forms of the final expression, which are essential for performing numerical calculations.

4. Miscellaneous Studies

Kartuzhanskiy, A. L., and V. A. Sokolova. Certain characteristics of the Herschel effect from a laser. ZhNiPFiK, no. 4, 1974, 287-288.

The effect of long-wave laser radiation on exposed photographic films is studied experimentally. Type MZ-3 and FT-20 films were first exposed to actinic radiation in a sensitometer, then to radiation from He-Ne (633 mμ), ruby (694 mμ), GaAs (850 mμ), or Nd (1060 mμ), lasers.

Typical results of sensitometric measurements (Fig. 1)

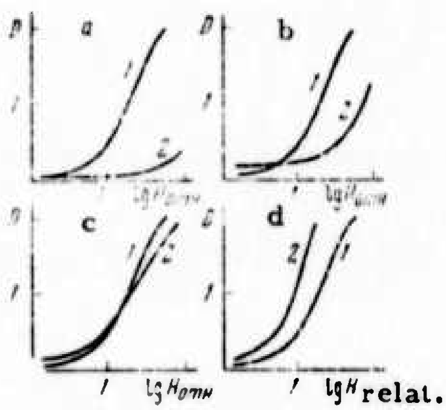

Fig. 1. Density-log exposure curves of MZ-3 film exposed in a FSR-41 sensitometer: curves 1- before and curves 2- after additional exposure to 1060 (a), 850 (b), 694 (c), and 633 mμ (d) laser radiation. Development according to GOST 10691-63 no. 4 standard for 4 min.

show that destruction of the latent image by action of the shortest wave-radiation (He-Ne) is completely suppressed by the actinic effect.

Destruction becomes more and more pronounced as the laser wavelength increases. Thus two competing processes, namely the Herschel and the actinic effects, occur simultaneously, as in the case of exposure to thermal radiation. There is also a similarity in the shift of the equivalent density D_P, i. e., the point of equal formation and destruction of a latent image.

The difference between laser radiation and thermal radiation effects is that the whole pattern of the Herschel effect from laser radiation is shifted toward longer wavelengths, in comparison with the same effect of thermal radiation. This shift is explained as the result of a two-photon process; however the cooperative mechanism, i. e., summation of the energy of two lasing photons, is not ruled out. Additional experiments with primary exposure to α - radiation of Po^{210} or β- radiation of C^{14}, and secondary exposure to a GaAs laser, shows a greater increase in D_P than in the experiment with primary exposure to the standard actinic radiation followed by GaAs laser exposure. This increase in D_P is due to a growth in dispersion of the latent image. The authors conclude that the Herschel effect from laser radiation is not completely analogous to the Herschel effect from thermal radiation of equal wavelength.

Gurevich, G. L., and V. A. Muav'yev. Effect of the spike structure of a laser pulse on the heating rate of thin films. FiKhOM, no. 3, 1974, 118-119.

The problem of local heating of thin films by laser radiation has been previously studied by the authors (FiKhOM, no. 1, 1973, p. 3). However, assumptions made there on the time consistency of

light flux intensity acting on the film do not always hold true in practice. In the present work, the earlier results are generalized for the case when the radiation intensity is a periodic function of time. An expression is derived which gives the behavior of temperature at the center of the illuminated zone. The criterion is determined, under which the spike structure of the laser pulses can be neglected during calculation of thermal fields, namely for the case when

$$\omega t_0 = \omega b^4 (\gamma / h)^2 / a_2 e^{C+2} \gg 1 \tag{1}$$

where h = film thickness, b = beam radius, and a_2 = coefficient of the thermal conductivity of film substrate; other values are defined in the earlier article (FiKhOM, no. 1, 1973, 3). The process of forming holes in a film by laser beam of small radius has a bright pulsed character, in contrast to the continuous hole formation during irradiation by a wide beam.

Krapivin, L. L., and L. I. Mirkin. Diffusion of gallium on a tin surface after irradiation by laser pulses and deformations. FiKhOM, no. 3, 1974, 22-25.

Propagation of the rectilinear diffusion front of gallium on a tin surface was investigated in crater regions, formed by laser and mechanical depressions in tin specimens under various conditions. For comparing the effect of imperfections and stress states of the material, studies were conducted on single crystals, deformed polycrystals, polycrystals under load, and materials subjected to laser pulses leading to a sharp rise in the number of defects in them. Gallium was deposited on the specimen surface in the form of strips, and the distance which

the diffusion zone travelled in a definite time interval, was measured by a microscope. Irradiation of the tin specimens was by a free-running 5 joule laser (otherwise unspecified).

Analysis of the diffusion mechanism taking place during recrystallization, and studies of diffusion layer cross-section, showed that the observed zone is a function of the volume diffusion. The rate of gallium diffusion in single crystals, polycrystals and plastically deformed tin single crystals is similar, and sharply increases around the crater region in tin under pressure. Graphical and microphoto data are included.

Dobrovol'skiy, I. P., and A. A. Uglov. Laser heating of solids, taking into account the temperature dependance of absorptivity. Kvantovaya elektronika, no. 6, 1974, 1423-1427.

This article treats the linear problem of heating a half-space by local surface heat source, distributed according to normal law, and allowing for the temperature dependence of absorptivity. It is assumed that the absorptivity is a linear function of temperature, or $A = \alpha + \beta T$, where A = absorptivity; α, β = coefficients, T = temperature, K. Equations are derived for flux q_o and energy E_o, necessary for heating the body to some temperature T, over an interval t. Solutions are obtained by the method of successive approximations.

Comparisons are made between results of the three-dimensional and one-dimensional problems. A qualitative difference is noted in the behavior of temperature with time in the above two cases. In one-dimensional problems, the temperature increases to infinity with time for $\beta \geq 0$ and tends to a stationary value at $\beta < 0$, while in the case of three-dimensional problems, the temperature always tends to a stationary value as $t \rightarrow \infty$. The authors include a table of α and β values for several metals.

Laser detonating [of remote charges].
Sotsialiticheskay industriya, July 4, 1974,
p. 4. (Translation)

A laser beam could be used for remote detonation of charges in open pit mining, according to specialists at the Scientific Research Institute of Mining at Tataban'ye (Hungary). An experiment was made with a liquid laser, developing bursts with brightness approaching that of lightning. With this device an explosion could be set off at a distance of several kilometers.

Hungarian engineers calculate that the new method, eliminating the need for Bickford fusing or electrical leads, would effect a significant economy in time and materials. In addition the safety factor would be appreciably greater.

Kovarskiy, V. A. Ye. A. Popov, I. A. Chaykovskiy, and N. F. Perel'man. Heatup effects in the interaction of high power laser radiation with a localized electron. FTT, no. 3, 1974, 943-945.

One of the most common opinions on the destruction mechanism of solids due to powerful laser pulses concerns the origin of "hot points" in crystals, at places where the periodicity in crystallic potential (different local centers, dislocations, etc.) is interrupted. Owing to local heating of micro-regions containing clusters of absorbing centers, thermoelastic stresses are generated, which lead to crack formation and finally to material destruction.

Pursuing this study, the present work discusses an important role of multiphonon processes which ensures the energy transfer from electron excitation to an oscillating subsystem. A model is considered of local centers, near which local oscillations are developed. Since the frequency of these oscillations, as a rule, significantly exceeds the frequency of crystalline oscillations, local phonons take an active part in optical and nonradiative transitions. In a brief statistical analysis the authors show that during quantum transitions of local electrons owing to laser radiation, many local phonons are generated, which can lead to an effective rise in temperature of the local phonon subsystem, significantly exceeding equilibrium.

5. Laser-Plasma Interaction

Basov, N. G., O. N. Krokhin, V. V. Pustovalov, A. A. Rupasov, V. P. Silin, G. V. Sklizkov, V. T. Tikhonchuk, and A. S. Shikanov. Anomalous interaction of high-power laser radiation with a dense plasma. ZhETF, v. 67, no. 1, 1974, 118-133.

Anomalies in reflection by a plasma of nanosecond pulses from a Nd laser are studied experimentally, and the results are interpreted from the standpoint of the theory of parametric resonance. The plasma of density $n_e = 10^{21}/cm^3$ was formed by focusing laser radiation on aluminum and polyethylene targets in a vacuum chamber (Fig. 1).

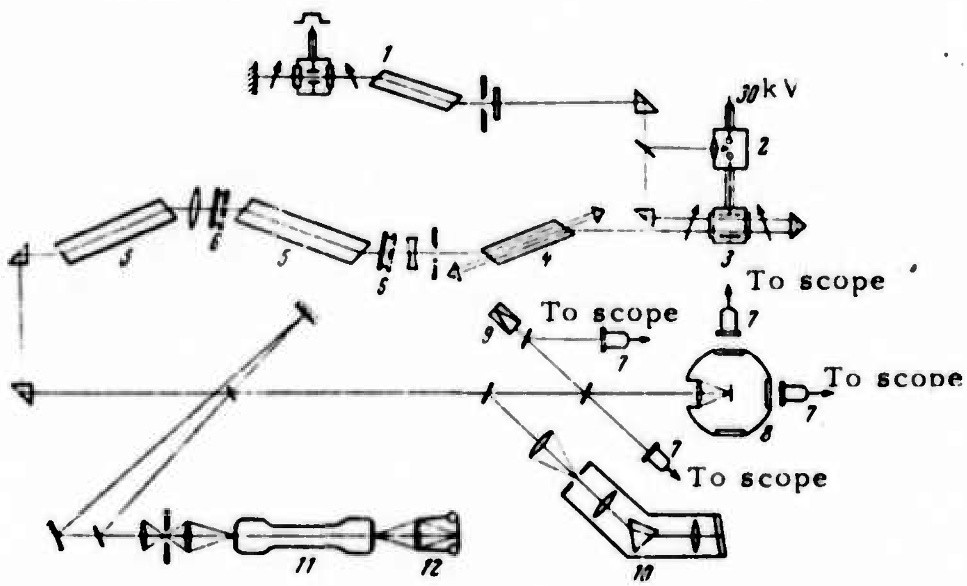

Fig. 1. Sketch of experiment: 1- Nd laser with Q-switching Kerr cell; 2- discharger with laser ignition; 3- pulse-shaping Kerr shutter; 4- three-pass amplifier; 5- second and third amplifiers; 6- cells with bleaching filter; 7- coaxial photocells; 8- vacuum chamber; 9- calorimeter; 10- prism spectrograph; 11- FER-2 photoelectric recorder; 12- camera.

Power density was in the range of 2×10^{12} -- 2×10^{13} w/cm^2. The Q-switched laser generated pulses of 3-4 nsec. duration with up to 10 j energy and about 10^{-3} rad divergence. Beam diameter arriving at the focusing lens (f = 5.5 cm) was 2.5 cm. and minimum time resolution of the system was 10^{-10} sec. Incident flux was varied with calibrated neutral light filters.

Three main anomalous effects were observed: almost total absorption of laser radiation by the plasma; time modulation of the weak reflected signal (Fig. 2); and generation of the radiation harmonics in the spectrum of reflected radiation (Fig. 3). The first cited effect is

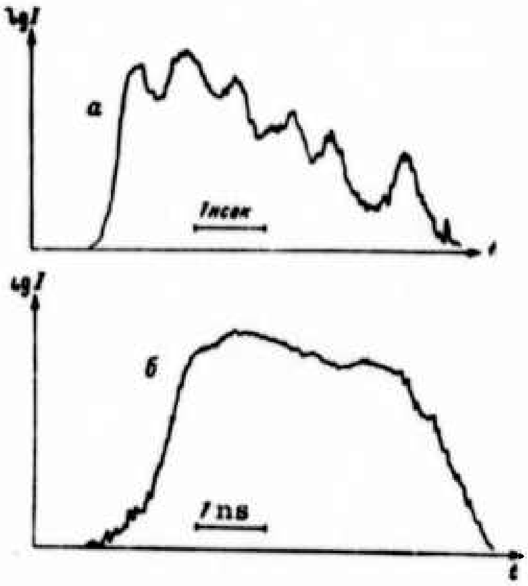

Fig. 2. Reflected (a) and incident (b) signals vs. time.

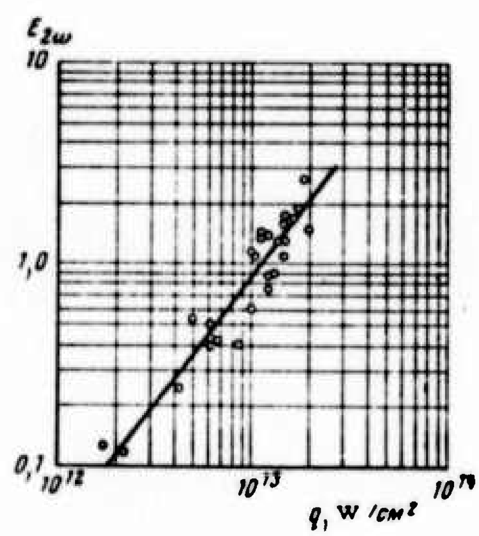

Fig. 3. Experimental plot of second harmonic energy $E_{2\omega}$ recorded in the solid angle of focusing lens, vs. incident flux density q.

illustrated by a continuous decrease (in case of Al) or constancy (in case of polyethylene) of reflection coefficient R as q is increased. The

theory of parametric resonance indicates that the experiment q values are within the range of near-threshold q values required for development of parametric instabilities in the plasma. At $q \geq q_{thr}$ absorption would be determined solely by parametric turbulence effects.

This interpretation of the observed anomalous effects points to the need for further studies aimed at optimization of parameters of the laser-plasma system, as required for controlled thermonuclear reaction. The authors note also that oscillations of reflected radiation, specifically measurements of the oscillatory period and modulation level of the reflected pulse, may be used for plasma diagnostics.

Aglitskiy, Ye. V., V. A. Boyko, S. M. Zakharov, L. A. Pikuz, and A. Ya. Fayenov. Identification of transitions from doubly excited levels of the Cℓ XV, K XVII, and Ca XVIII lithium like ions in a laser plasma. KSpF, no. 12, 1973, 12-15.

X-ray spectral wavelengths of the Cℓ XVI, K XVIII, and Ca XIX He-like ions, with ionization potentials of 3.658, 4.611, and 5.179 keV, respectively, were measured and the $1s^2pn\ell$ $1s^2n\ell$ type transitions between energy levels of Li-like Cℓ XV, K XVII, and Ca XVIII ions were identified in a laser plasma. X-ray spectra were obtained with sharp focusing of incident radiation at 5×10^{14} w/cm^2 density during 8 to 10 laser pulses. The measured wavelengths, accurate to ± 0.0005 Å, and the corresponding transitions from doubly excited levels of all cited ions are tabulated, along with the theoretical wavelengths and relative intensities calculated by Aglitskiy et al. earlier, on the assumption of a dielectronic recombination mechanism of population of the doubly excited levels.

The measured 4.4474 and 4.4516 Å wavelengths of Cℓ XV ions, and the 3.5357 and 3.1809 Å wavelengths of K XVII and Ca XVIII ions are assumed to represent $1s^2p^3p \rightarrow 1s^23p$ type transitions, on the basis of an earlier identification of the corresponding Aℓ XI line and extrapolation of the authors' experimental data on Mg X - V XXI isoelectronic series. Apparently, the 4.5215 Å and 3.5880 Å weak and broadened lines of Cℓ XV, and K XVII, respectively, correspond to the group of 7 theoretical lines representing $1s^2p^2\,{}^4P \rightarrow 1s^22p\,{}^2P$ and $2s2p[{}^3P]1s\,{}^4P \rightarrow 1s^22s\,{}^2S$ transitions, respectively.

Bykovskiy, Yu. A., N. N. Degtyarenko, V. F. Yelesin, Yu. P. Kozyrev, V. V. Kondrashov, Ye. Ye. Lovetskiy, A. N. Pol'yanichev, L. M. Sil'nov, B. Yu. Sharkov, and V. S. Fetisov. Experimental and theoretical studies of multicharged ions in a laser plasma. 11th Int. Conf. Phenomena in Ionized Gases, Prague, 1973, 260. (RZhF, no. 6, 1974, 6G244). (Translation)

Spatial and energy distributions of multicharged ions have been studied in a laser plasma, produced by focusing a laser beam at 5×10^{13} w/cm^2 power density on the surface of a light element (Aℓ, C). A time of flight mass spectrometer was used. The energy spectrum of ions with different masses were focused to be similar. A pronounced degree of recombination and acceleration for some ions was detected. A solution is given to the problem of plasma expansion into a vacuum. The maximum ion energy and its dependence on the initial dimensions of the plasma are determined, as well as the amount of fast particles and their acceleration time. The theoretical relations obtained are compared with test measurements.

Kaliski, S. and E. Wlodarczyk. Plane supersonic heat wave with [variable] velocity in an ideal gas. Biuletyn WAT J. Dabrowskiego, v. 22, no. 10, 1973, 21-36. (RZhMekh, 4/74, no. 4B259). (Translation)

A closed solution is given for characteristics of the problem of a plane supersonic heat wave propagating with variable velocity into a half-space filled with ideal gas. In regions of asymptotic approximation a simple analytical solution was obtained. Results may be used in plotting averaged solutions for laser heating of plasma, accounting at the same time for heat and shock wave fronts.

Kaliski, S. Effect of precompression onthe optimal cumulation of a plane shock wave. Biuletyn WAT J. Dabrowskiego, v. 22, no. 10, 1973, 37-42. (RZhMekh, 4/74, no. 4B257). (Translation)

The effect of detonation-type precompression on reducing the energy required in the basic laser compression pulse is analyzed. It is shown that for precompression of the order 20-25 this reduction amounts to 75% at a cumulation of 10^3 to 10^4. In another article by the same author (Biuletyn WAT J. Dabrowskiego, vol. 22, no. 11, 1973) a similar though more extensive analysis is made, specifically for concentrated spherical waves where the reduction coefficient is even higher.

Kaliski, S. Plane shock waves moving at a constant velocity in a plasma heated by thermal conduction. Bull. Acad. Polon. Sci., Ser. Sci. Techn., v. 22, no. 5, 1974, 39[439]-43[443].

Conditions are analyzed for plane thermal wave propagation at a constant velocity D through a one- or two-temperature laser plasma. Propagation at D = const. can then be described by a set of two or three differential equations, respectively. Solution of these equations is obtained so as to satisfy the requirements $X_o = Dt$ or $T_e^m \approx r T_e^{m-1}$, where X_0 is the coordinate of the thermal wave front and m = 7/2, for one- or two-temperature plasma respectively.

In the former case, for m = 7/2, the laser pulse profile which would ensure a constant D is given by the expression of laser radiation intensity

$$F_0 \sim t^{2/5}. \tag{1}$$

and temperature profile is given by

$$T_0 \sim t^{2/5} \tag{2}$$

Solution of the fundamental equations for a one-temperature plasma, with allowance for the thermal effect of thermonuclear fusion, gives at t = 0 (the initial phase of heating):

$$T_0(t) \approx t^{2/5}, \tag{3}$$

and

$$F_0(t) \sim At^{2/5} - \beta t^{12/5}. \tag{4}$$

In the case of a two-temperature plasma and the cited approximation, the solution is given in the form

$$T_e \sim \alpha t^{2/3}; \quad T_i \sim \beta t^{2/3}; \quad F_0 \sim \gamma t^{2/3}. \tag{5}$$

where the coefficients α, β, and γ are formulated on the basis of the fundamental equations and on the assumption that T_e and T_i are of the same order of magnitude. The author concludes that the laser pulse profile can be shaped to generate a thermal wave propagating toward the plasma center at a constant rate D. A similar effect can be obtained with a spherical thermal wave, specifically a convergent concentric wave, as discussed in another paper.

Kaliski, S. Effect of precompression on an optimally cumulated plane shock wave. Bulletin de L'Academie Polonaise des sciences, Serie des sciences techniques, v. 22, no. 3, 1974, 21(239)-25(243).

The effect of precompression on the critical value of laser pulse energy for a concentric spherical wave was discussed by the author in a previous work (Proc. Vibr. Probl., 14(1973); 15(1974), no. 1). The present work takes up the case of plane waves.

A perfect gas subjected to compression by a plane shock wave in a tube of length L is considered and an expression is derived for the energy of optimum compression, making use of the equation of state. It is shown that for a precompression of 20 to 25 and a net compression of 10^3 to 10^4 the critical energy of compression reduces by 75% (Fig. 1). This

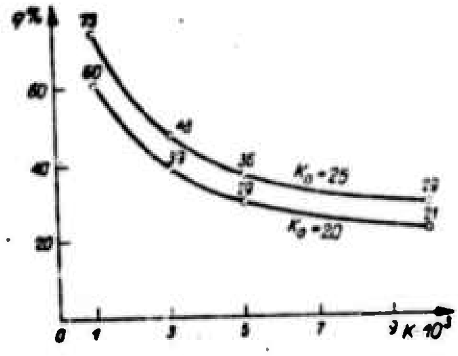

Fig. 1. Reduction in critical energy of compression η vs. maximum compression K. (K_0 - precompression).

effect is quite significant for thermonuclear fusion by means of laser compression. In the case of spherical waves the reduction is still higher, so that explosive precompression should enable one in practice to reduce the critical energy of a laser pulse for thermonuclear fusion by about one half. The precompression effect thus gives a new possibility of essential reduction in the critical value of the laser energy pulse, which is vital to the laser fusion technique.

Kaliski, S. Profiled concentric shock compression of a plasma ball in the framework of a simplified model. Bull. Acad. Polon. Sci., Ser. Sci. Techn, v. 22, no. 5, 1974, 243[381]-250[388].

A simplified averaged description of concentric shock compression of a plasma ball, as introduced earlier by the author (Proc. Vibr. Probl., v. 15, no. 1, 1974), is extended to the case of a profiled (time-variable) laser pulse pressure, $p_c = p_c(t)$. The averaged equation

of motion at the surface of the plasma ball with profiled compression is solved, as in the cited paper, by integration in quadratures, i.e., by the substitution

$$x^{2\nu} D^2 = U, \tag{1}$$

where $x = R/R_0$ is the ratio of the shock-wave front coordinate to the initial radius of the plasma ball, and D is the velocity of the shock wave front.

On the assumption that the external pressure $p_c = p_c(x)$ at the surface of the plasma ball varies similarly to $p_c(t)$, the equation of motion in the form

$$\frac{dU}{dt} + q(x)\,U + f(x), \tag{2}$$

is solved for U. From this it is possible to determine D; velocities v_s and v_p of particles at the shock wave front and at the surface of the plasma ball; $p(r)$; and $\rho(r)$ $(R \leq r \leq R_0)$. To simplify integration of (2), the pressure profile

$$p_c(x) = p_{c0}(1-x)^n, \tag{3}$$

where $n > 1$, is introduced, which represents growth of p_c in the compression interval from zero to p_c0. Further analysis is given which permits selection of optimal p_c profiles.

The present solution may be extended to a nonhomogeneous body with a programmed nonhomogeneity profile, thus making the compression process isentropic. In addition, the solution may be used as the basis for developing more general equations of profiled plasma compression by laser with allowance for the shock and thermal wave fronts and for thermonuclear fusion.

Kaliski, S. Laser compression and plasma synthesis. Biuletyn WAT J. Dabrowskiego, vol. 22, no. 10, 1973, 3-20. (RZhMekh, 4/74, no. 4B279). (Translation)

This is a survey of studies on concentric compression of plasma. Special attention is paid to the method of averaged description worked out by the author. A method of laser concentric heating of a plasma with precompression by cumulative explosive charges is proposed. This method results in additional reduction of critical energy of the laser pulse necessary for the positive energy generation in synthesis. It is shown that critical energy of the laser pulse may in this case be reduced to 1 - 3 kilojoule.

Ignatov, A. B., I. I. Komissarova, G. V. Ostrovskaya and L. L. Shap .o. Interference-holographic study of a laser spark. IN: Sb. Diagnostika plazmy, no. 3, Moscow, Atomizdat, 1973, 162-166. (RZhF, 4/74, no. 4G345). (Translation)

A thorough interference-holographic study of a laser-induced spark in hydrogen and helium under 1-11 atm. pressures was carried out. Laser pulse energy for generating the spark was 0.2 joule. A portion of laser emission, directed through the focal plane prior to plasma formation therein, passed through a KDP crystal and was used to obtain holograms with two emission wavelengths. Upon processing the interferograms it was possible to obtain time-space distributions of electron concentration through the volume of the laser spark: in helium at 6 atm; in hydrogen at 1.75, 3, 6, and 11 atm; and in air at 1.75 atm. Electron concentration is at its maximum in spark zones directly exposed to laser emission. It is noted that when the laser spark is generated in gases under high initial pressure,

the gradients of electron concentration are significantly higher than the corresponding concentration gradients under low pressure. From reconstructed holographic images of the laser spark it was possible to compute the velocity of the lateral expansion of plasma, as well as the velocity of plasma movement towards the laser beam. The measured values of velocities are in good correspondence with the hydrodynamic mechanism of breakdown.

Grigor'yev, V. A., V. Yu. Zalesskiy, N. N. Nikolayevskaya, M. L. Chepkalenko and P. I. Shkuropat. Mach-Zender optical interferometer for studying the density of a linear theta-pinch plasma. IN: Sb. Diagnostika plazmy, no. 3, Moscow, Atomizdat, 1973, 166-168. (RZhF, 4/74, no. 4G346) (Translation).

An interferometric apparatus was devised for investigating plasma density of a linear theta-pinch two meters in length. Plasma contained in a vacuum chamber was placed in one arm of a Mach-Zender interferometer, arranged in the form of a horizontal П-shaped frame welded of channel bars; to limit the transmission of vibrations the frame had a double damping suspension. The plates and mirrors (diameter - 170 mm, thickness - 30 mm) of the interferometer were of optical quartz and their surfaces finished with an accuracy of up to 0.3 fringe. In the flanges of the discharge chamber the thickness of quartz windows was 30 mm. A ruby laser is used as the basic source of light. The interference image of fringes of equal thickness, developing in time, was recorded by the SFR high-speed camera operating in a streak mode (?). To decrease exposure time of each frame the laser was used under special operating conditions generating a series of short light pulses of 0.2 microsec each. Thus it is possible to have several consecutive interferograms corresponding to different discharge phases.

Boyko, V. A., Yu. P. Voynov, V. A. Gribkov and G. V. Sklizkov. Determining electron temperature from spectra of multicharged ions in laser plasma. IN: Sb. Diagnostika plazmy, no. 3, Moscow, Atomizdat, 1973, 90-92. (RZhF, 4/74, no. 4G339). (Translation)

To measure electron temperature T_e of a dense laser plasma formed by irradiating a condensed substance in vacuum, it was decided to use relative intensities of spectral lines in the vacuum u-v spectral region within the range of 100-200 Å. The laser flare spectrum over a range of 30-2000 Å was recorded by a DSF-6 vacuum spectrograph with a gilded lattice of 600 lines/mm, having a radius of 1 meter and a 0.004 mm slit. Spectrograms were obtained which helped to identify new lines of ions: Ca XIII - Ca XV: K XIII - K XV; Fe SVIII; Se XIV - Se XVI; Ti XIV - Ti XVI. From the example of processing spectrograms of a calcium plasma, it was shown how to determine T_e for all the above ions, since all of them possess a similar structure of levels.

Breton, K., V. Seka and Zh. L. Shvob. Use of multilayer targets for investigating a laser-generated plasma. IN: Sb. Diagnostika plazmy, no. 3, Moscow, Atomizdat, 1973, 92-97. (RZhF, 4/74, no. 4G340)

In order to clarify the mechanism of ion generation with a low degree of ionization in a laser-produced plasma, additional experiments were conducted using 200 Mw lasers with 40 nanosec pulse duration. For this purpose multilayer targets were employed consisting of several flat layers of variable thickness and different material (aluminum, plastic). Three possibilities of ion generation were considered: 1) recombination of hot plasma while it expands in front of the target; 2) direct generation of ions through ionization of the thin layer on the fringe

of the laser-irradiated zone where the intensity of laser emission is lower; 3) direct formation of ions on the crater bottom heated at the end of the laser pulse. Tests and analyses of obtained spectra revealed that the main cause of ion generation with a low degree of ionization (Al^{3+}; C^{4+}) is recombination, since the above ions exist only in the area before the target where electron densities are too low to allow for heating of the plasma. It is noted that the use of multilayer targets makes it possible to separate the phenomenon of recombination in laser-induced plasma from superimposed secondary effects in the form of an unstable plasma. Computation of the final degree of ionization of aluminum and carbon plasma, based on standard recombination coefficients and on the Dawson model for the spherical expansion of plasma, has produced values that satisfactorily correspond to experimental data.

Zaydel', A. N., G. V. Ostrovskaya and Yu. I. Ostrovskiy. Holographic methods for studying plasma. IN: Sb. Diagnostika plazmy, no. 3, Moscow, Atomizdat, 1973, 136-147. (RZhF, 4/74, no. 4G343). (Translation)

Special features of holographic methods as applied to plasma investigation are presented. When a light wave passes through plasma the plasma undergoes phase and amplitude distortions due to absorption and scattering of light. Holograms enable one to record the passing of light waves through plasma and to study all the changes brought about by various optical methods, such as interferometric, shadow, Schlieren, etc. By means of a holographic method it is possible to illuminate plasma simultaneously in different directions and accordingly to determine the spatial distribution of plasma parameters. One of the peculiarities of the holographic method is its insensitivity to plasma self-radiation. The holographic interference method is analyzed in detail; it is the most accurate and widely used method for investigating phase nonuniformities. Estimates of sensitivity of the above method are given and ways of increasing its effectiveness are discussed. Results of investigations involving the application of the holographic method are listed and basic measurement diagrams and experimental technology are fully described.

Yakhoda, F. K. Pulsed holographic interferometry (review). IN: Sb. Diagnostika plazmy, no. 3, Moscow, Atomizdat, 1973, 147-162. (RZhF, 4/74, no. 4G344).

Principles of a holographic method of plasma investigation are comprehensively presented. Concrete diagrams of a holographic interferometer for measuring plasma density in various devices are given. Drawbacks and problems of holographic motion picture interferometry, used to obtain a time sequence of interferograms within one experiment, are discussed.

Zakharenkov, Yu. A., N. N. Zorev, A. A. Kologrivov, N. A. Konoplev, G. V. Sklizkov, and S. I. Fedotov. Interferometricheskoye issledovaniye gazodinamicheskikh protsessov, proiskhodyashchikh v initsiiruyemom lazernym izlucheniyem razryade (Interferometric investigation of gasdynamic processes taking place in a laser-initiated discharge). Moskva, 1973, 30 p. (RZhF, 3/74, no. 3D1111). (Translation)

Gasdynamic processes taking place in a discharger with laser ignition are investigated by methods of dual-frame and two-color high-speed interferometry. A method is developed for processing interferograms, based on the approximation of interference band displacements in orthonormal sets of Chebyshev polynomials, for subsequent calculation of electron density in a computer. The method is claimed to be highly accurate. Distribution of electron density in the discharge gap was experimentally studied at 4 atm and under various conditions. It was found that during focusing of a laser beam on the electrodes, a gas-warmup zone, resulting in a shock wave, is developed as a result of heat transfer by nonequilibrium radiation. Relationships of time lag in breakdown relative to the laser pulse are determined as a function polarity, energy and wavelength of the laser. It is shown that formation of electric signals with duration$\approx 10^{-11}$ sec is possible.

Denus, S., Z. Jankiewicz, S. Kaliski, et al. Generation of thermonuclear neutrons in plasma formed by powerful pulsed laser heating. Biul. WAT J. Dabrowskiego, v. 22, no. 8, 1973, 3-13. (RZhF, 2/74, no. 2G409). (Translation)

Experimental results are described of generating a high-temperature plasma and producing thermonuclear neutrons, during irradiation of lithium deuteride and deuterated polyethylene microparticles by nanosecond laser pulses with pulse energy of 20-40 joules.

Kaliski, S. Simplified averaged equations of concentric laser compression of a plasma. Proc. Vibrat. Probl. Pol. Acad. Sci., v. 14, no. 2, 1973, 105-115. (RZhF, 2/74, no. 2G388) (Translation)

Equations are developed for describing averaged concentric compression parameters of a deuterium-tritium plasma under the effect of laser radiation. A Fermi liquid model is used for describing the compressed central portion of the target. The external expanding cloud is treated as an ideal gas. A system of nonlinear integro-differential equations is derived, the solution of which can be found by analog computer. It is suggested that in subsequent studies, a workable model should be developed, such that the interaction of the expanding external plasma layers with the compressed substance could be taken into account more accurately; and also that equations should be derived which would account for thermal and shock waves.

Jach, K., S. Kaliski, and R. Swierczynski. Numerical analysis of simplified averaged equations of laser spherical compression of a plasma. Biul. WAT J. Dabrowskiego, v. 22, no. 8, 1973, 43-52. (RZhF, 2/74, no. 2G405). (Translation)

Numerical calculations are presented for laser spherical compression of a plasma. It is shown that positive energy generation is

possible for a laser pulse with an energy of about 5 kjoule in the case of D-T pellets with radius = 3.5×10^{-2} cm. Comparisons are made with calculations based on other models.

Kaliski, S. Effect of precompression on the optimum cumulation of a plane shock wave. Biul. WAT J. Dabrowskiego, v. 22, no. 8, 1973, 37-42. (RZhF, 2/74, no. 2G415). (Translation)

The effect of explosive compression of a substance is considered as a means of reducing the required energy of a laser compression pulse. It is shown that for a compression factor of about 20-25, this reduction can amount to 75%. A similar analysis is conducted for a concentric spherical wave, in which case the coefficient of energy reduction is still higher. The effect of preliminary compression thus opens up the possibility of lowering the critical value of laser pulse energy needed for igniting thermonuclear reactions.

Burakov, V. S., A. F. Bokhonov, V. V. Zhukovskiy, P. A. Naumenkov, and S. V. Nechayev. Methods for active laser diagnostics of a plasma. IN: Sb. Materialy 2-y Vses. Konf. po plazmennym uskoritelyam, 1973. Minsk, 1973, p. 333. (RZhF, 3/74, no. 3G320). (Translation)

Effects of powerful laser flux are considered on a low-temperature plasma. The nature of variations in absorbing properties of the plasma is related to the value of temperature change and the presence of equilibrium in it. Critical laser radiation flux is estimated. Plasma studies were conducted outside as well as inside the laser resonator. In using intra-resonator methods of plasma diagnostics, the sensitivity actually achievable in determining optical plasma density was about 0.004 for a gas laser and ~0.02-0.03 for a solid-state. The effect of absorption saturation, as observed in the case of

coincidence of laser radiation frequency with discrete transitions of the atomic system, is suggested to be used for determining the concentration of absorption centers. The method was verified with a potassium plasma. It is noted that based on the considered effects, it is possible to determine nonlinearity parameters of the plasma, as well as its coefficients of absorption and dispersion.

Silin, V. P. Parametricheskoye vozdeystiye izlucheniya bol'shoy moshchnosti na plazmu. (Parametric effect of powerful radiation on plasma). Moskva, Izd-vo Nauka, 1973, 287 p. (RZhF, 3/74, no. 3G205). (Translation)

This monograph is devoted to a new fast-developing field in physics: interaction of powerful e-m radiation with plasma. The main concepts are described of the nonlinear parametric effect of radiation on plasma, for which resonance instability is a characteristic, leading to plasma oscillation excitations, followed by growth of internal field fluctuations and formation of turbulent conditions. Laboratory investigations are discussed which led to experimental verification of the predicted theory: the phenomenon of anomalously rapid transfer of e-m field energy to the plasma, corresponding to the anomalously high HF-resistance of the turbulent plasma state. All these relationships apply to r-f as well as the laser radiation range, so that they are universal to a large extent.

Babenko, A. N., L. N. Vyacheslavov, E. P. Kruglyakov, and V. N. Semenov. Studying the structure of collisionless shock waves in plasma according to Thomson scattering of light. IN: Sb. Diagnostika plazmy. No. 3. Moskva, Atomizdat, 1973, 213-217. (RZhF, 3/74, no. 3G41). (Translation)

When a shock wave in plasma intersects a laser beam of constant power in a direction normal to it, the scattering signals precisely reproduce the time structure of the shock wave front. Two laser systems are described with powers of 20 and 30 Mw, which provide pulse generation of significant duration (1 and 100-150 μs). The possibility of long pulse methods as applied to plasma investigations is estimated. An experiment was conducted on a UN-6 device using a conventional low-powered laser (~15 Mw). Measurements were taken of the density in the pre-plasma region and behind the shock wave (10^{13} cm^{-3} and 3×10^{13} cm^{-3}, respectively). Measurements of electron temperature using a high power laser showed that the temperature equalled 0.4 ev in the pre-plasma and 5 ev in the plasma behind the shock wave.

Aleksandrov, V. V., A. I. Gorlanov, N. G. Koval'skiy, S. Yu. Luk'yanov, and V. A. Rantsev-Kartinov. Diagnostics of a direct self-pinched discharge by a laser radiation scattering method. IN: Sb. Diagnostika plazmy. no. 3. Moskva, Atomizdat, 1973, 200-206. (RZhF, 3/74, no. 3G321). (Translation)

Parameters of a Z-pinch at the moment of maximum plasma column compression were measured by the method of laser radiation dispersion.

The discharge tube diameter was 20 cm and its length, 100 cm. Experiments were conducted in hydrogen at initial pressures 0.1-0.3 torr. Maximum value of the discharge current was 30 ka and period = 15 μsec. A laser pulse of 20 nsec duration and 2.5 joules energy, generated by a Q-switched ruby was focused at the discharge chamber center by a long-focus lens (f = 1 m). Dispersion was observed at a 90° angle to the main beam. The intersection region of the plasma column with the normal laser beam was projected to the input port of an MDR-2 monochromator. The investigated radiation from the monochromator was fed through six fiber optic-channels to separate FEU-52B photomultipliers, signals from which were then fed to an amplifier through a system of delay lines, and were then recorded in a single beam in an oscillograph with a time shift. Plasma density was simultaneously measured from broadening of H_{α} and H_{β} lines. The necessary resolving time was ensured by using an electro-optic Kerr cell; exposure time did not exceed 30 nsec. The electron temperature of the plasma could be determined independently by measuring relative intensities of the spectral lines of carbon impurity. Ion peak scattering was recorded. The combination of all obtained results permitted the determination of density, and electron and ion temperatures of the plasma in a compressed column with a high accuracy plus good time and spatial resolution.

Malyshev, G. M., and G. T. Razdobarin. <u>Plasma diagnostics according to scattering of laser radiation</u>. IN: Sb. Diagnostika plazmy. No. 3. Moskva, Atomizdat, 1973, 177-200. (RZhF, 3/74, no. 3G319). (Translation)

The method of investigating a plasma according to its laser radiation dispersion makes it possible to measure local plasma parameters with good spatial and time resolutions over a wide range of concentrations and temperature. Experimental results are very reliable, and in comparison

to other methods they depend little on additional assumptions regarding the character of spatial, time and energy distribution of particles in the plasma. A summary is given of works relating to plasma diagnostics by means of laser radiation dispersion. Results are described of the theoretical calculations according to Thomson and collective scattering of laser radiation by plasma. Plasma parameters are established, which can be determined by the measured radiation dispersion spectrum. Limits to the use of the dispersion method are estimated. A series of experimental studies are outlined which concern plasma diagnostics by laser dispersion, and the results obtained are discussed.

Mishin, Ye. V. Temperature of a plasma corona of a D-T droplet, heated by laser. DAN SSSR, v. 215, no. 3, 1974, 565-566.

Electron temperature T_e in the plasma corona is the most important characteristic for an effective laser thermonuclear fusion. The present work accordingly arrives at simple formulas for electron temperature as a function of absorbed laser energy in the plasma corona. Laser energy is assumed to be absorbed in a layer whose thickness L is much less than the plasma corona dimensions (e.g. when absorption is determined by parametric instability, $L = 10^{-3}$-10^{-2} cm while the radius of the drop = 0.1-1 cm). Initially the electron temperature is not high enough, so that electron heat flux inside the drop is less than absorbed laser energy, and temperature increases therefore in the layer. This temperature rise stops when the heat is balanced by thermal conductivity. Characteristic heating time here is much less than the laser pulse duration, so that the whole process can be considered as quasistationary.

The equation of balance is derived for electron temperature, together with a system of expressions for particle interaction with turbulent pulsations. From the combined solution of these equations, the author derives a simple expression for electron temperature T_e.

Ostrovskaya, G. V., and N. A. Pobedonostseva. Study of the spatial distribution of the plasma parameters of a laser spark according to the contour of the H_α absorption line. ZhTF, no. 3, 1974, 671-674.

The spatial distribution of plasma parameters of a laser spark was investigated in detail. Local parameters were determined by the diagnostic device described earlier by Yevtushenko, et al. (ZhTF, 1971, 2581). The absorption spectrum obtained in this case corresponded to a definite moment of plasma generation (exposure duration ~60 nsec), and energy distribution in the spectrum along the height of the line corresponded to different portions of the plasma.

The radial distribution of absorption coefficient at the center of H_α line $k_{\lambda 0}$ (r/r_0) for a laser spark in hydrogen at a pressure 3 atm was calculated (Fig. 1).

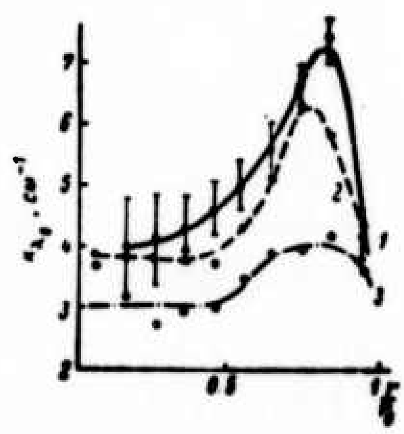

Fig. 1. Radial distribution of absorption coefficient at the center of H_α line.

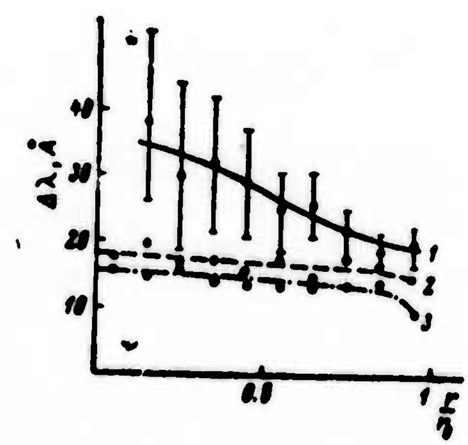

Fig. 2. Local values of H_α line widths.

For both figures, τ in μsec:

1) -0.8; 2) - 1.3; 3) - 1.7

The relationship $k_\lambda(r/r_0)$ can be similarly found for different distances from the center of the absorption line, which enables one to construct local contours of the absorption line. Fig. 2 shows the local values of the linewidth $\Delta\lambda$ by means of which the following values were determined: 1) electron concentration, N_e, 2) concentration of absorbing atoms, N, 3) atom concentration in the normal state N_0, and 4) temperature T.

Table 1 shows the maximum, minimum and average values of $k_{\lambda 0}$, $\Delta\lambda$, N_e, N, N_0 and T, and also values of these parameters determined according to the integral (along central cross-section) contour of the H_α lines.

Table 1

	T, μsec											
	0.8				1.3				1.7			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
$k_{\lambda 0}$, cm^{-1}	7.4	4.0	5.0	5.0	6.3	3.8	4.5	4.5	4.1	3.0	3.4	3.6
$\Delta\lambda$, Å	38	20	27	26	18	15	17	18	16	10	14	14
$N_e\cdot 10^{-17}$, cm^{-3}	8.6	3.0	5.2	4.0	2.8	2.1	2.8	2.8	2.2	1.1	1.9	1.8
$N\cdot 10^{-16}$, cm^{-3}	1.8	1.0	1.3	1.3	1.0	0.6	0.7	0.7	0.50	0.40	0.42	0.44
$N_0\cdot 10^{-17}$, cm^{-3}	10.0	0.8	2.7	1.8	7.0	1.5	3.7	2.9	7.7	1.7	3.2	2.8
T, deg.	23000	17000	18800	18700	17000	14400	15700	16000	16000	12000	15100	15000

I - Maximum value; II- minimum;
III - average; IV - integral.

It was found that propagation of the shock wave front, occurring during gas breakdown by laser, as well as the density profile behind the shock wave, can be explained well by the theory of a point explosion. However, this theory is not suitable for describing plasma parameters in the central portion of laser spark, because of the finiteness in volume of the energy release during laser spark formation.

Dolgov-Savel'yev, G. G., and V. N. Karnyushin.
Study of plasma produced by the action of a laser beam on a lithium deuteride target. IN:
Sb. Diagnostika plazmy. No. 3. Moskva,
Atomizdat, 1973, 172-177.

This article describes studies of a laser plasma generated by irradiation of drifting LiH particles by Nd glass laser pulses. Dimensions of the particles were 0.1-0.3 mm, chamber pressure - 10^{-5} torr, laser beam flux density at the focus - 5×10^{10} watt/cm, and the half-width of the pulse was 30 nsec. Two coils were used to generate a magnetic field in the focus region of screw configuration, developing up to 20 kgs in the median plane. Investigations were done using two methods:

1. Optical diagnostics. A single-stage PIM-3 electron-optical converter was used for scanning plasma illumination, with a resolving time on the order of 2 nsec. Electron density of the plasma was measured by the optical interferometry method using a Mach- Zender interferometer; density in the region transparent to the probing beam reached 3×10^{18} cm^{-3}. The overall number of electrons in the plasma region at the moment of laser pulse termination $N_e = 3 \times 10^{16}$, assuming spherical symmetry.

2. Magnetic probe measurement. Variations of external magnetic field were measured by means of a single-coiled probe of 25 mm diameter, made up of kovar wire and enclosed in a protective glass tube of O. D. = 0.8 mm. Probes were placed at different distances from the focus and angled 90° to the laser beam axis. The change in average magnetic flux was measured by a single-coil probe of 2 cm diameter.

The authors' conclusions are as follows:

1. Retardation and confinement of the external plasma layer takes place at distances about 5 mm from the center.

2. The spatial picture of the change in magnetic field indicates a radial decrease in induced current density, j, with distance from the center. This is probably due to the decrease in temperature T and dispersion velocity v of the plasma ($j \sim T^{3/2} vB$; B = const.).

3. The magnetic field of the current in the expanding plasma can be approximated as a dipole field. Calculations with such approximations show that the magnetic field is totally displaced by plasma in a volume of up to 2 mm radius during an interval of 100 nsec from the start of a laser pulse.

Gamaliy, Ye. G. Calculating the compression and heating of experimental deuterated polyethylene targets. ZhETF P, v. 19, no. 8, 1974, 520-524.

Calculations are discussed on heating and compression of spherical deuterated polyethylene targets, under uniform laser radiation. Numerical calculations are developed for spherically-symmetrical heating of targets, with reference to the experimental data of Basov et al. in their 9-beam experiment (ZhETF P, v. 15, 1972, 589). Laser radiation is introduced in calculation e form of energy flux on the target surface at the Lagrangian boundary. Results of the calculations are compared with test data of Basov's group (Table 1). It is concluded that in practice it may be possible to achieve a 30-fold compression in the central part of the target.

Table 1

Target Nos.	Initial target dimension	Experimental data			Calculated results	
№	r, cm	E, j	T, ev	N_{exp}	N	T^e_{max}, ev
1	$2{,}5 \cdot 10^{-2}$	600	40	–	–	700
2	$1{,}25 \cdot 10^{-2}$	202	120	–	–	800
3	$5{,}5 \cdot 10^{-3}$	214	840	$3 \cdot 10^{6}$	10^{6}	10^{3}
4	$3 \cdot 10^{-3}$	232	$4 \cdot 10^{3}$	–	–	$4{,}5 \cdot 10^{3}$

E - laser energy; N - Neutron yield; T^e_{max} - maximum electron temperature in evaporation region.

Stavisskiy, Yu. Ya. Problem of using supercompression of substances by reactive pressure for obtaining neutron pulses. ZhETF P, v. 19, no. 8, 1974, 548-551.

The author considers possible ways of generating intensive neutron pulses for physical investigations. A pulsed neutron source based on direct laser excitation of nuclear reactions was discussed previously by Brugger (Nucl. Technology, 15, 14, 1972). He showed that at a laser pulse energy = 10^4 kj, released during ~ 10^{-9} sec, approximately 13.6 x 10^{19} neutrons are emitted in a D-T pellet of 10^{-2} gm. If the pulse repetition frequency = 0.1 Hz, then the average neutron intensity equals ~ 3.6 x 10^{18} neutron/sec at an average heat release in the system = 10 Mw and average laser beam power = 1 Mw.

The laser power required would be significantly less if neutron pulses were generated by means of chain reactions in micro-critical masses of the fissionable material, obtained during super-compression of the material in the laser beam. This is shown in the work by Askar'yan et al (ZhETF, 17, 1973,597), where a neutron intensity of 10^{16} neutron/sec and heat release of $\sim$ 1 Mw was obtained at an average laser power of about 10 kw.

It is pointed out that the possibility of obtaining critical masses of fissionable substance, as given in Askar'yan's work, may still not provide a method of generating neutron pulses of sufficient intensity at low amplitude scattering. For obtaining intensive neutron pulses, it is necessary to have a significantly increased nucleus density over the critical and, correspondingly, an increased multiplication factor over unity. It is hence necessary to have an external neutron irradiation source of high intensity. The author suggests that such an irradiation source may be obtained by using (a) proton irradiation with energy = 600 Mev, such as from the accumulator-buncher of the Institute of Nuclear Research, AN SSSR (duration of bunch = 2.5×10^{-8} sec, peak current = 5 a); (b) a powerful electron beam from one-shot pulsed electron accelerators: or (c) neutrons from a D-T reaction, if the ablation layer of the specimen contains a deuterium-tritium mixture.

Fisher, V. I. Laser breakdown of air in a fixed electric field. ZhETF, v. 66, no. 5, 1974, 1668-1672.

The experimentally observed dependance of the optical breakdown threshold of air on constant electric field is theoretically explained.

In a constant electric field, drift velocity of electrons U is proportional to the field intensity E, while the joule heating of electrons varies as E^2. Therefore, for an increase of E the breakdown threshold at first increases due to drift of electrons from the focal region, and then starts decreasing, because the joule heating of electrons in a sufficiently strong constant electric field facilitates the development of avalanching more than it inhibits the driftoff of electrons. Ultimately, optical breakdown is restricted by the electric breakdown between electrodes, whose threshold E is determined by the pressure and properties of the filler gas. Optical breakdown by CO_2 laser radiation,for example, can have only an avalanche character, because the $\hbar\omega$ is too low for multiphoton ionization of molecules. The development of electron avalanche requires the presence of initial 'start up' electrons. A detailed discussion is given on the mechanism of these electron formations and expressions are derived for optical breakdown.

In conclusion, the author points out that for pressures $p > 30$ torr, the optical breakdown threshold decreases significantly for an increase of E to more than 1000 v/cm before the combined optical and electrical breakdown takes place. For $p = 1$ torr, electrical breakdown takes place at $E^* \sim 700$ v/cm and electric field increases the optical breakdown threshold by a few percent. For $p < 1$ torr, E^* increases with decrease of p and the optical breakdown threshold decreases with the increase of $E > 800$ v/cm. All other conditions for these observations are the same as given in the work by Tulip and Seguin (Appl. Phys. Lett, 23, 135, 1973).

6. SOURCE ABBREVIATIONS

AiT	-	Avtomatika i telemekhanika
APP	-	Acta physica polonica
DAN ArmSSR	-	Akademiya nauk Armyanskoy SSR. Doklady
DAN AzSSR	-	Akademiya nauk Azerbaydzhanskoy SSR. Doklady
DAN BSSR	-	Akademiya nauk Belorusskoy SSR. Doklady
DAN SSSR	-	Akademiya nauk SSSR. Doklady
DAN TadSSR	-	Akademiya nauk Tadzhikskoy SSR. Doklady
DAN UkrSSR	-	Akademiya nauk Ukrainskoy SSR. Dopovidi
DAN UzbSSR	-	Akademiya nauk Uzbekskoy SSR. Doklady
DBAN	-	Bulgarska akademiya na naukite. Doklady
EOM	-	Elektronnaya obrabotka materialov
FAiO	-	Akademiya nauk SSSR. Izvestiya. Fizika atmosfery i okeana
FGiV	-	Fizika goreniya i vzryva
FiKhOM	-	Fizika i khimiya obrabotka materialov
F-KhMM	-	Fiziko-khimicheskaya mekhanika materialov
FMiM	-	Fizika metallov i metallovedeniye
FTP	-	Fizika i tekhnika poluprovodnikov
FTT	-	Fizika tverdogo tela
FZh	-	Fiziologicheskiy zhurnal
GiA	-	Geomagnetizm i aeronomiya
GiK	-	Geodeziya i kartografiya
IAN Arm	-	Akademiya nauk Armyanskoy SSR. Izvestiya. Fizika
IAN Az	-	Akademiya nauk Azerbaydzhanskoy SSR. Izvestiya. Seriya fiziko-tekhnicheskikh i matematicheskikh nauk

IAN B	-	Akademiya nauk Belorusskoy SSR. Izvestiya. Seriya fiziko-matematicheskikh nauk
IAN Biol	-	Akademiya nauk SSSR. Izvestiya. Seriya biologicheskaya
IAN Energ	-	Akademiya nauk SSSR. Izvestiya. Energetika i transport
IAN Est	-	Akademiya nauk Estonskoy SSR. Izvestiya. Fizika matematika
IAN Fiz	-	Akademiya nauk SSSR. Izvestiya. Seriya fizicheskaya
IAN Fizika zemli	-	Akademiya nauk SSSR. Izvestiya. Fizika zemli
IAN Kh	-	Akademiya nauk SSSR. Izvestiya. Seriya khimicheskaya
IAN Lat	-	Akademiya nauk Latviyskoy SSR. Izvestiya
IAN Met	-	Akademiya nauk SSSR. Izvestiya. Metally
IAN Mold	-	Akademiya nauk Moldavskoy SSR. Izvestiya. Seriya fiziko-tekhnicheskikh i matematicheskikh nauk
IAN SO SSSR	-	Akademiya nauk SSSR. Sibirskoye otdeleniye. Izvestiya
IAN Tadzh	-	Akademiya nauk Tadzhiksoy SSR. Izvestiya. Otdeleniye fiziko-matematicheskikh i geologo-khimicheskikh nauk
IAN TK	-	Akademiya nauk SSSR. Izvestiya. Tekhnicheskaya kibernetika
IAN Turk	-	Akademiya nauk Turkmenskoy SSR. Izvestiya. Seriya fiziko-tekhnicheskikh, khimicheskikh, i geologicheskikh nauk
IAN Uzb	-	Akademiya nauk Uzbekskoy SSR. Izvestiya. Seriya fiziko-matematicheskikh nauk
IBAN	-	Bulgarska akademiya na naukite. Fizicheski institut. Izvestiya na fizicheskaya institut s ANEB
I-FZh	-	Inzhenerno-fizicheskiy zhurnal

IiR	-	Izobretatel' i ratsionalizator
ILEI	-	Leningradskiy elektrotekhnicheskiy institut. Izvestiya
IT	-	Izmeritel'naya tekhnika
IVUZ Avia	-	Izvestiya vysshikh uchebnykh zavedeniy. Aviatsionnaya tekhnika
IVUZ Cher	-	Izvestiya vysshikh uchebnykh zavedeniy. Chernaya metallurgiya
IVUZ Energ	-	Izvestiya vysshikh uchebnykh zavedeniy. Energetika
IVUZ Fiz	-	Izvestiya vysshikh uchebnykh zavedeniy. Fizika
IVUZ Geod	-	Izvestiya vysshikh uchebnykh zavedeniy. Geodeziya i aerofotos"yemka
IVUZ Geol	-	Izvestiya vysshikh uchebnykh zavedeniy. Geologiya i razvedka
IVUZ Gorn	-	Izvestiya vysshikh uchebnykh zavedeniy. Gornyy zhurnal
IVUZ Mash	-	Izvestiya vysshikh uchebnykh zavedeniy. Mashinostroyeniye
IVUZ Priboro	-	Izvestiya vysshikh uchebnykh zavedeniy. Priborostroyeniye
IVUZ Radioelektr	-	Izvestiya vysshikh uchebnykh zavedeniy. Radioelektronika
IVUZ Radiofiz	-	Izvestiya vysshikh uchebnykh zavedeniy. Radiofizika
IVUZ Stroi	-	Izvestiya vysshikh uchebnykh zavedeniy. Stroitel'stvo i arkhitektura
KhVE	-	Khimiya vysokikh energiy
KiK	-	Kinetika i kataliz
KL	-	Knizhnaya letopis'
Kristall	-	Kristallografiya
KSpF	-	Kratkiye soobshcheniya po fizike

LZhS	-	Letopis' zhurnal'nykh statey
MiTOM	-	Metallovedeniye i termicheskaya obrabotka materialov
MP	-	Mekhanika polimerov
MTT	-	Akademiya nauk SSSR. Izvestiya. Mekhanika tverdogo tela
MZhiG	-	Akademiya nauk SSSR. Izvestiya. Mekhanika zhidkosti i gaza
NK	-	Novyye knigi
NM	-	Akademiya nauk SSSR. Izvestiya. Neorganicheskiye materialy
NTO SSSR	-	Nauchno-tekhnicheskiye obshchestva SSSR
OiS	-	Optika i spektroskopiya
OMP	-	Optiko-mekhanicheskaya promyshlennost'
Otkr izobr	-	Otkrytiya, izobreteniya, promyshlennyye obraztsy, tovarnyye znaki
PF	-	Postepy fizyki
Phys abs	-	Physics abstracts
PM	-	Prikladnaya mekhanika
PMM	-	Prikladnaya matematika i mekhanika
PSS	-	Physica status solidi
PSU	-	Pribory i sistemy upravleniya
PTE	-	Pribory i tekhnika eksperimenta
Radiotekh	-	Radiotekhnika
RiE	-	Radiotekhnika i elektronika
RZhAvtom	-	Referativnyy zhurnal. Avtomatika, telemekhanika i vychislitel'naya tekhnika
RZhElektr	-	Referativnyy zhurnal. Elektronika i yeye primeneniye

RZhF	-	Referativnyy zhurnal. Fizika
RZhFoto	-	Referativnyy zhurnal. Fotokinotekhnika
RZhGeod	-	Referativnyy zhurnal. Geodeziya i aeros"-yemka
RZhGeofiz	-	Referativnyy zhurnal. Geofizika
RZhInf	-	Referativnyy zhurnal. Informatics
RZhKh	-	Referativnyy zhurnal. Khimiya
RZhMekh	-	Referativnyy zhurnal. Mekhanika
RZhMetrolog	-	Referativnyy zhurnal. Metrologiya i izmeritel'naya tekhnika
RZhRadiot	-	Referativnyy zhurnal. Radiotekhnika
SovSciRev	-	Soviet science review
TiEKh	-	Teoreticheskaya i eksperimental'naya khimiya
TKiT	-	Tekhnika kino i televideniya
TMF	-	Teoreticheskaya i matematicheskaya fizika
TVT	-	Teplofizika vysokikh temperatur
UFN	-	Uspekhi fizicheskikh nauk
UFZh	-	Ukrainskiy fizicheskiy zhurnal
UMS	-	Ustalost' metallov i splavov
UNF	-	Uspekhi nauchnoy fotografii
VAN	-	Akademiya nauk SSSR. Vestnik
VAN BSSR	-	Akademiya nauk Belorusskoy SSR. Vestnik
VAN KazSSR	-	Akademiya nauk Kazakhskoy SSR. Vestnik
VBU	-	Belorusskiy universitet. Vestnik
VNDKh SSSR	-	VNDKh SSSR. Informatsionnyy byulleten'
VLU	-	Leningradskiy universitet. Vestnik. Fizika, khimiya
VMU	-	Moskovskiy universitet. Vestnik. Seriya fizika, astronomiya

ZhETF	-	Zhurnal eksperimental'noy i teoreticheskoy fiziki
ZhETF P	-	Pis'ma v Zhurnal eksperimental'noy i teoreticheskoy fiziki
ZhFKh	-	Zhurnal fizicheskoy khimii
ZhNiPFiK	-	Zhurnal nauchnoy i prikladnoy fotografii i kinematografii
ZhNKh	-	Zhurnal neorganicheskoy khimii
ZhPK	-	Zhurnal prikladnoy khimii
ZhPMTF	-	Zhurnal prikladnoy mekhaniki i tekhnicheskoy fiziki
ZhPS	-	Zhurnal prikladnoy spektroskopii
ZhTF	-	Zhurnal tekhnicheskoy fiziki
ZhVMMF	-	Zhurnal vychislitel'noy matematiki i matematicheskoy fiziki
ZL	-	Zavodskaya laboratoriya

7. AUTHOR INDEX